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Status of Walleye spawning population in Coteau Bay, Lake Diefenbaker 1998-2000

Fish and Wildlife Technical Report 02-1

Recycled Paper

103-00547/

STATUS OF THE WALLEYE SPAWNING POPULATION IN COTEAU BAY, LAKE DIEFENBAKER, 1998 TO 2000

by

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Fish and Wildlife Technical Report 02 - 1

December 2001

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EXECUTIVE SUMMARY

For 10 years, the sole source of walleye eggs for the provincial stocking program has been the walleye that spawn in Coteau Bay (adjacent to Gardiner Dam) on Lake Diefenbaker, Saskatchewan. An assessment of this population was conducted from 1998 to 2000. A more general assessment of walleye in the entire lake or at all potential spawning sites was not feasible during this study.

Since 1991, Saskatchewan Environment and Resource Management (SERM) staff have recorded several indicators of walleye population health during hatchery operations. Number of females, number of eggs per female, hatch success, and other observations show no significant variations over time. Very few observations were either higher or lower than expected for a stable situation. Several of these indicators would require long-term monitoring to detect any changes inconsistent with the natural fluctuations in walleye populations.

During April and May of 1998 to 2000, hatchery and project staff caught, measured, and examined more than 15,000 walleye in Coteau Bay. The tagging portion of the study was done at Coteau Bay in May, and at the Riverhurst angling tournament in June, 1998. Estimates of age composition were based on the lengths of walleye measured at Coteau Bay. Mortality rates were calculated from other survey data. Several angling tournaments were monitored between May 1998 and July 2000. A toll-free number was provided through the Provincial Enforcement Centre for anglers to report recaptures year-round.

Walleye spawning in Coteau Bay range from 23 to 77 cm long with females being substantially longer and heavier than males. Female spawners reach 20 years of age. The males were up to about 15 years of age. Both have relatively low mortality in this population. The spawners tend to be much larger than those caught by angling in 1983.

Between 1998 to 2000, anglers reported more than 300 recaptures of tagged walleye. Ten percent of these fish had moved more than 90 kilometres by July, and a few had moved 145 kilometrers to the Beaver Flats area by September. There is some indication that they move away from Coteau Bay by swimming randomly, but directed migration is possible. More research is needed to confirm whether any pattern exists that could be used to estimate walleye abundance throughout the lake.

The minimum number of individual spawners in Coteau Bay is between 11,000 and 22,000, based on recaptures of tagged fish one and two years after release. There may be up to 36,000 individual spawners, based on daily recaptures during tagging in 1998. Both methods of population estimates have advantages and disadvantages: the first must adjust for mortality and loss of tags and recruitment of first-time spawners, while the second depends on tagged fish reaching trap-net sites without delay.

The assessment to date shows the walleye population using Coteau Bay has not been noticeably affected by spawn-camp operations. The number of females and males caught, numbers of eggs per female, hatching success of eggs, and sizes and ages of both sexes indicate a relatively stable situation over time and by comparison to other populations. Only one of six indicators showed a change; the proportion of females to males in 2000 catches declined. Should the proportion of females to males in catches continue to decline in the next few years there may be cause for concern.

This assessment covers only walleye that migrate into Coteau Bay for spawning and does not consider spawning at other sites. Some walleye from Coteau Bay move most of the way up the lake by late summer, and some tagged in the Riverhurst area in June move into Coteau Bay by the next spring.

Recommendations:

1. There should be an assessment of whether the walleye in Coteau Bay are being sustained by contributions from other spawning populations which would mask problems in Coteau Bay, and lead to impacts on both hatchery operations and the lake-wide population. An understanding of intermixing among spawning sites in Lake Diefenbaker is required.

2. The effects of biological assessment, catch-and-release angling, harvest mortality, and year-class strengths should be investigated over time in any future work. Indicators should be compared with other spawning populations in Lake Diefenbaker.

3. Monitoring of spawning walleye in Coteau Bay during hatchery operations should continue. Additional information on egg characteristics and indicators of disease or stress would be useful. Researchers should continue to fine-tune egg collections according to natural abundance of eggs each year.

ACKNOWLEDGMENTS

Many people were invaluable in making this plan a workable project.

Fish Culture Station: Greg Mitchell, Shawn Baldock, Gerry Banks, and Ron Phillips monitored spawn camp operations and provided specimens and support for our work.

EcoRegion and Branch: Syd Barber, Hugh Hedger, Dennis Sherratt, Rick Sanden, and Dave Brewster provided funds and staff for this work; Kevin Murphy, Don McKinnon, Maynard Chen, Bruce Howard, Dale Hjertaas, and Jennifer Merkowsky provided advice on the study design of this report.

Tagging Team: Peter Ashcroft, Hugh Hedger, Darrell Stan, Wayne Luchenski, Sue McAdam, Troy Hilts, Nicole Bang, Jennifer Merkowsky, Bruce Hagel, Marcel Ferland, Lorne Sullivan, Tom Coolidge, Ken Costley, Dwight Mullholland, Rick Wright and Wayne Lightfoot spent many hours measuring and tagging fish.

Volunteers: Derek Birkshaminisi, Dana Thoreson, Adam Carlson and Meagan Ashcroft enthusiastically spent their own time measuring and tagging fish.

Provincial Enforcement Centre: Dave Harvey, Keith Dahl and staff answered the Park Watch line and summarized information from anglers for 1998 through 2000.

Tournament Organizers: Brian Cafferatta and the Elbow & District Wildlife Federation provided us access and assistance at their "Lake Diefenbaker Walleye Classic." We were also assisted by Gayle Langer and the Riverhurst Recreation Board during their "Riverhurst Walleye Classic," and Dale Hope and the Kyle Chamber of Commerce and Kyle Lions Club at their "Saskatchewan Landing Walleye Tournament."

Sports Writers: Michael Snook and Wayne Phillips provided newspaper and other coverage and encouraged anglers to participate in the project.

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1.0 INTRODUCTION

Since the early 1920's, Saskatchewan Environment and Resource Management (formerly the Department of Natural Resources) has carried out a walleye (*Sander vitreus*) stocking program to supplement or restore native populations or to provide anglers with newly stocked waters. For decades, eggs have been obtained from spawning walleye at field camps at various sites in April and May, fertilized on location, and transported to the provincial Fish Culture Station at Fort Qu'Appelle for incubation and later distribution of fry (larvae). Many former sites, such as Crean Lake, Bad Carrot Creek and Cowan River are not presently used for logistical and other reasons.

For ten years, the sole provincial source of eggs has been the spawning walleye in Coteau Bay on Lake Diefenbaker. This spawning congregation was first explored in 1985 and annual operations began in 1991 (Greg Mitchell pers. comm.). Each spring 3,000 to 6,000 walleye were caught in trap-nets by hatchery crews over three to four weeks. Between 60 and 110 million eggs were collected for province-wide use (Gerry Banks and Greg Mitchell pers. comm.).

Lake Diefenbaker, Figure 1, was created in 1967 by construction of the Gardiner Dam on the South Saskatchewan River for hydro-electric and irrigation purposes. The lake has an FSL of 557 m (Royer 1972) and the reservoir extends 222 km from Gardiner Dam upstream. The lake area is 430 square km and it has 760 km of shoreline at peak elevation (Saskatchewan Environment 1988). About half the lake area is more than 15 m deep and about one quarter is more than 30 m deep. Maximum depths range from 21 m upstream near Saskatchewan Landing to 59 m near Gardiner Dam. Similarly, mean depths of 14.6 to 30.5 m and mean widths of 1.6 to 3.1 km are lower upstream and higher near the dam. Draw downs are typically 3 to 11 m over winter.

Coteau Bay is at the downstream end near Gardner Dam and spillway, and is about five km long and up to one km wide under typical spring conditions (Figure 2).

Hatchery and EcoRegion staff recommended an assessment of the status and health of the Coteau Bay population several years ago (Gerry Banks and Greg Mitchell pers. comm., Ron Jensen pers. comm.). Provincial hatchery operations for eight years on Crean Lake had not affected year-classes and the health of the population was good, according to federal researchers in 1984 (Mathias et al. 1985). Yet occasionally, problems are known to develop at long-term spawn-taking operations.

The objectives for the study were to assess walleye in Coteau Bay specifically. Trends in sizes, sex ratios, hatching success, and other indicators from annual records since 1991 were examined and the number of spawners, sizes and ages, and reproductive indicators were determined from field work between 1998 and 2000. Post-spawning dispersal of walleye and the angling patterns of tournament and recreational anglers were explored. The survey was designed by Grassland EcoRegion and Fish & Wildlife Branch to run co-operatively alongside hatchery spawn-taking operations.

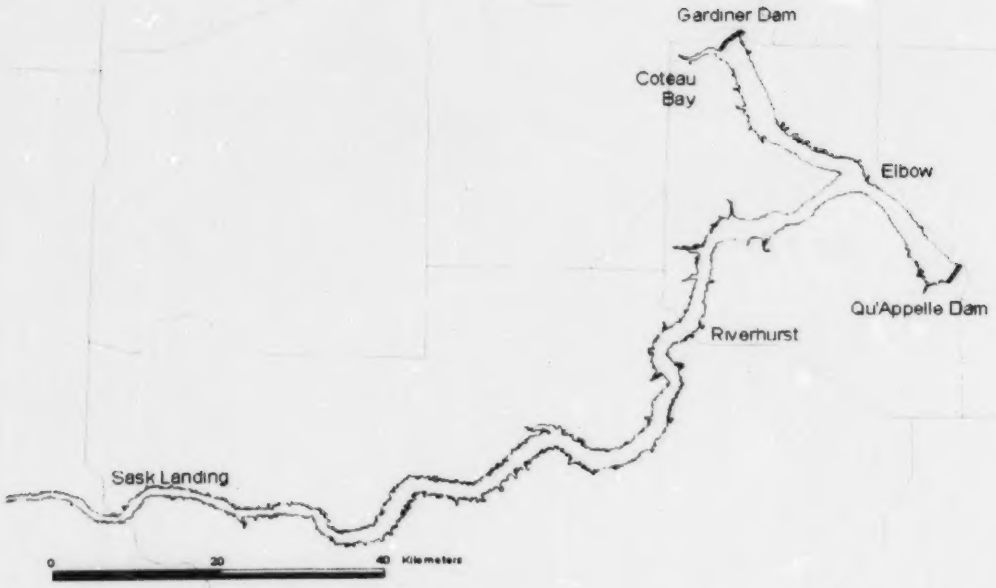

Figure 1. Map of Lake Diefenbaker, Saskatchewan.

Outflows from Gardiner Dam continue down the south Saskatchewan River; smaller outflows from Qu'Appelle Dam go into the south-eastern water-control area.

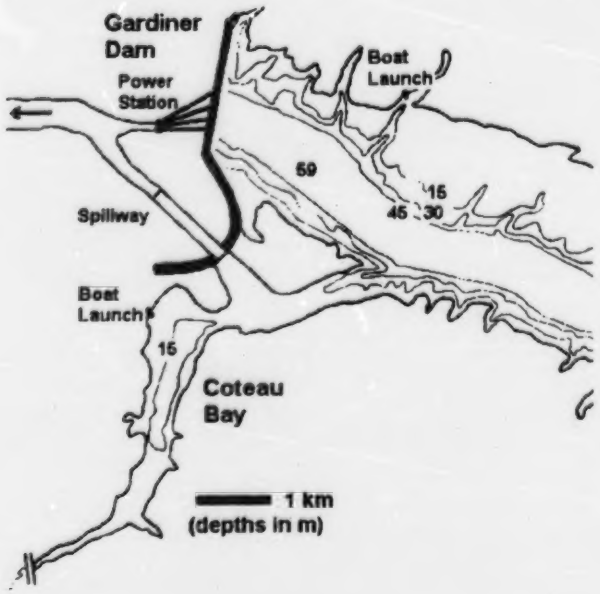

Figure 2. Map of Coteau Bay, located at the western end of Gardiner Dam.

Literature on walleye populations across North America suggested there may between 250,000 and five million adult walleye in Lake Diefenbaker (Baccante and Colby 1996). Staff are aware of numerous other likely spawning areas on the lake (Gerry Banks, Dean Grisdale, Ron Jensen, and others pers. comm.).

Walleye occur throughout the Saskatchewan River system (Miles and Sawchyn 1988, Royer 1972). However, a survey showed "remnants of the native river population [were] rare" a few years after Lake Diefenbaker was created (Royer 1972). Walleye fry (larvae) were planted to augment the natural population, starting with more than eight million fry in 1969-1970, and periodically since that time. Since 1991, the provincial hatchery has returned two to six million fry annually to Coteau Bay as part of a policy to augment natural reproductive capacity that was removed by walleye spawn collection (Appendix 1).

General surveys of fish populations have periodically been conducted on Lake Diefenbaker. These include 1967-69 in Royer (1972), 1973 in Smith (1974), 1983 and 1985 (Maynard Chen and Leroy Royer pers. comm.), 1992 in Jensen and Merkowsky (1992), and 1995 (Jennifer Merkowsky and Ron Jensen pers. comm.).

2.0 METHODS

2.1 SPAWN CAMP

Fish culture staff from Fort Qu'Appelle operate a walleye spawn camp from late April to mid-May with four or five trap nets set at suitable locations in Coteau Bay. The trap nets are checked at least once daily. All fish are counted and identified, walleye are retained for spawning operations while other species are released at the nets.

Staff place the walleye into aerated tanks and they are transported by boat to shore. They are visually sorted as ripe and running or green fish. Eggs and sperm are manually stripped from ripe and running fish. Fertilized eggs are clayed, water-hardened and retained on site for a few days until transported to the hatchery Green female walleye are kept in holding pens up to three days for ripening. At the end of the three days, the females have either been stripped of eggs or are released into Coteau Bay to spawn.

Since 1991, hatchery staff have recorded several indicators of walleye abundance such as numbers of females, number of eggs, and rate of successful hatching (Table 1). These data were analysed for trends, both visually and statistically (NWP 1998). A relative index was created by dividing data collected by their own mean, since data differ greatly (from fractions to per cent to thousands). Preliminary time series analyses of auto-correlations and partial auto-correlations were done.

2.2 SIZES AND AGES

Project assessment crews worked alongside fish culture operations. Walleye were measured, marked and released from four sources: male walleye not needed for spawning and all spawned-out females seen at each trap-net, walleye released after daily egg collections, unripe female walleye which remained after three days in camp, and walleye remaining in pens at the end of spawn camp.

Fish were not sacrificed for assessment in 1998 - 2000. Since age materials were not collected routinely, age-length keys for females and males were based on a variety of sources: summer open-lake surveys in 1992 and 1995, spawning specimens in 1996 (Greg Mitchell pers. comm.), and necropsy specimens from a tumour study in 1998 (Cam Portt pers. comm.).

Mortality rates of walleye in Coteau Bay were based on size compositions of females and males caught between 1998 and 2000, and age-length keys for each sex were developed from previously mentioned sources.

Table 1. Number of walleye and walleye eggs, Coteau Bay spawn-camp, 1991-2000 [a].

YEAR	NUMBER			NUMBER OF EGGS		
	MALES	FEMALES	FEMALES SPAWNED	COLLECTED	PER FEMALE	HATCH
				(millions)	(thousands)	(%)
1991	1754	1478	484	60.9	125	56
1992	0	0	0	0.0	...	...
1993	1738	1351	525	78.4	149	56
1994	2464	1731	642	97.7	152	51
1995	1395	1569	918	112.9	123	45
1996	1278	1072	648	93.7	145	51
1997	1947	1424	679	113.0	166	57
1998	2657	1696	768	105.0	136	52
1999	3938	2518	717	99.5	140	49
2000	3868	1181	649	96.7	149	55
Average	2338	1558	670	95.31	...	...

[a] Data are from Fish Culture Station annual records.

2.3 TAGGING

Coteau Bay

In 1998, crews recorded catches and recaptures of tagged fish by individual trap-net. This proved very difficult and was not continued in 1999 or 2000. In all three years, newly tagged fish were released at the shore-camp location to avoid extra holding and handling to transport them back to trap-net sites.

Walleye were tagged with metal "chicken wing tags" clamped into their operculum (Ketchum Manufacturing Ontario, size 2, in two colours and labeled "SERM"). Silver tags numbered 0001 to 5000 were used at Coteau Bay and red tags numbered 10000 to 11000 were used at Riverhurst. Staff had previous good results with this wing tag on lake whitefish and noted serious infections and ulcers from other kinds of tags (T-bar and dart tags) in walleye in Buffalo Pound Lake.

In addition to the metal tags in 1998, a leather hole punch was used to punch a hole in the 5th spine of the spiny dorsal ray (called DP) as a permanent mark. About one-quarter of the walleye got metal tags, another quarter got a DP, and half got both. Marking each animal with two kinds of tags, and recording those recaptures with only one and those with both kinds, provides an estimate of the number which lose their tags (Seber 1973). We recorded details for all recaptures in 1999 and 2000.

In 1999 and 2000, hole-punches were used as a year mark. In 1999, the upper second ray of the caudal fin near its base was punched (called CP) on both new and recaptured fish. In 2000, the second ray of the right pelvic fin was punched (called PP). Holes in the spiny dorsal ray remained obvious for two years (whether missing or regrown as a thick callus), while those in caudal fins were less obvious after one year and frequently had to be confirmed by feel.

Riverhurst

Walleye were also tagged in Palliser Regional Park near Riverhurst (about 60 kilometres up the reservoir) to determine if walleye migrate to Coteau Bay to spawn. Tournament organizers agreed to provide all walleye for tagging after the official "weigh-in" at Rusty's Marina. An estimated 1,000 walleye, sauger (*Sander canadense*) and sauger/walleye hybrids (saugeye) were expected. Only walleye were tagged with red wing-tags numbered from 10,000 and released into the marina area. Sex of these walleye was not discernible at this time of year.

2.4 ABUNDANCE

Absolute numbers of walleye were estimated separately using mark-recaptures within year and between years. Daily records of mark-recaptures were used to estimate the number of walleye in Coteau Bay within each year. Data were analyzed for three day periods (called the Schnabel binomial method) or the entire three week survey (Schnabel or Jolly-Seber methods).

"Closed" or "open" populations in Coteau Bay were assumed for within-year estimates. Simply, a "closed" population remains at a constant abundance without any loss of fish (from death or emigration), any new recruits (from immigration or growth), or any behaviour that changes their susceptibility to capture. During spawning season, some of these assumptions are probably not true. An "open" population undergoes any of these losses, additions, or changes, which is a biologically more realistic assumption. However, this complexity means more data are needed, usually estimates are less precise, and sometimes the statistics are not easy to interpret. No correction for any tag loss within each year were made, since scars from missing tags were observed in only a few fish.

Each year was treated as a single tag or recapture period to estimate abundance in each previous year (Petersen method). A corrected number of fish was obtained to approximate a "closed" population for 1998 and 1999. First, numbers of recaptures were adjusted (especially metal tags with serial numbers) for tag losses, which effectively corrects for both loss of the tag and/or the fish. Second, the number of untagged fish examined in the present year were adjusted by removing the estimated number of first-time spawners. Third, adjustment were done for any tendency by individual fish that arrived earlier in 1998 to arrive earlier again in 1999. To estimate the entire population (rather than only the "early" or "late" part), fish needed to be mixed randomly in their arrival times in 1999 and 2000.

Tagged and untagged walleye were assumed to behave alike in returning to Coteau Bay or going to another site in the following year. If this is reasonable, it means that abundance in the previous year can be estimated, regardless of the proportion that does not return.

The term "number of individual walleye" refers to the number of different individual fish over the entire spawning period, after converting from the number present on each day (some of which are the same individuals).

2.5 ANGLING

Tournament

Organizing committees for the three "Catch and Release" tournaments held annually on Lake Diefenbaker were approached for assistance. An opportunity was requested to describe the study to anglers, obtain information from anglers who recaptured tagged fish, and interview anglers dockside when they weighed-in their daily catch. The interview was kept brief by asking only for numbers of fish and locations. Cooperation was encouraged by low-key private conversations, and the assurance that specific information gained would not be divulged to anyone during the tournaments.

Recreational

Recreational anglers were advised about the study through signs (Appendix 2) posted at lake-side fish cleaning sites, SERM offices, lake access points, and newspaper articles. Anglers were encouraged to report tagged walleye caught by providing a toll-free number for reporting. The number was set up with live telephone operators (800-667-1788, SERM Park Watch, Keith Dahl pers. comm.). There was no attempt to survey recreational angling on Lake Diefenbaker directly.

Sports Writers

Two Saskatchewan sports writers specializing in angling news were provided with information for an article. Two major city papers, *The Star Phoenix* in Saskatoon and *The Leader-Post* in Regina, carried articles about the project in the fishing column of their Sunday editions. *The Outdoor Edge*, the journal produced by the wildlife federations of western Canada, also published an article describing the program.

2.6 MOVEMENTS

Post-spawning movements from Coteau Bay were followed based on angler reports. Walleye were also tagged at the Riverhurst catch-and-release tournament in June to demonstrate movements from other areas into Coteau Bay the following spring. It was recognized that these fish may have spawned near Riverhurst, in Coteau Bay, or elsewhere in the spring of 1998.

There were limitations to some recapture data, mostly due to the tendency of anglers to move into areas where walleye were known to concentrate. This meant that locations with more frequent recaptures were indicative of both angling effort and walleye movements.

2.7 REPRODUCTION

Reproductive capacity is the total number of eggs in all mature females in Coteau Bay. Part of the study was to check if egg collections were a substantial proportion of this capacity. Rough estimates for the population were done using hatchery records, lake-wide surveys, and extrapolations. Maturity curves from summer surveys on the lake showed that only a few fish in Coteau Bay may have been immature, although this was not confirmed by internal examination.

Females were not sacrificed for precise counts of eggs in individual females. Only estimates of the number obtained by stripping were available from annual records. Totals were recorded for each shipment of eggs (collected over several days), but are reported as annual averages per female since 1991.

Average fork lengths of female walleye at spawn-camp were not suitable for detailed calculations. Fecundity (that is, the number of eggs per female) is usually related more to weight than length. Also, average lengths will under-estimate average weight, so each length was converted to predicted weight using a log-log regression from summer surveys. Summer weights of females without ripe eggs seemed a suitable measure for fecundity.

3.0 RESULTS

3.1 SPAWN CAMP

Hatchery staff have observed that walleye catch rates are generally better in years with low water levels. Multiple linear regressions for 1991 to 2000 (except 1992) showed that both low water level and more effort tend to increase catch rates of females. Together these factors explained 78 % of variation in catch per unit effort (CPUE) rates:

$$CPUE = 36.49 + (2.20 * \text{water level}) - (0.39 * \text{effort}),\ n = 9,\ r^2 = 78\%$$

where CPUE is number of females caught per trap-net night, water level is m below FSL at Gardiner Dam, and effort is trap-net nights (Greg Mitchell unpubl. data). Both factors are statistically significant, neither factor is recommended for removal from the regression, and auto-correlations and multi-collinearity between factors are not statistical problems.

Likely, efforts are increased in years with lower CPUE (and reduced in years with high catch rates) to maintain sufficient numbers of females and eggs during operations. This follows from the fact that fishing with more trap-nets for more nights should not increase catch rates. Since other factors vary and the time series is not long, no further conclusions can be drawn although water level may remain a useful practical indicator.

Records show catches of 12 fish species since 1991 (Table 2) during spawn taking operations. Sucker species other than white sucker : (longnose sucker, quillback, shorthead redhorse, and silver redhorse) are not listed in Table 2. Another nine species recorded in other studies have not been seen in trap-nets (such as lake trout, lake sturgeon, emerald shiner, trout-perch, and spoonhead sculpin). Some of these are rare and some are too small for trap-nets to retain.

Most indicators of walleye abundance, sex ratios, numbers of eggs, and hatchability of eggs showed few, if any, trends from 1991 to 2000 (data were missing for 1992 because there was no operation at Coteau Bay.). Number of females varied, reaching a low in 1996 and high in 1999; proportion of females in catches was notably lower in 2000; fecundity (that is, average number of eggs per female) varied only slightly (Figure 3).

Table 2. Fish species caught in Coteau Bay during walleye spawn camp. [a]

YEAR	NTPK	WHSC	LKWH	RBTR	BUBR	CISO	BKTR	GOLD	SAUG	YLPR	ATSL	MOON
1991	98	790	248	0	17	2	0	1	1	0	0	0
1992	...	...	...	...	...	...	...	...	...	.....	...	...
1993	874	1490	287	0	62	0	0	7	0	0	0	0
1994	906	1771	216	21	182	6	1	2	1	0	0	0
1995	765	3425	425	54	106	18	0	1	1	5	2	0
1996	529	1497	431	27	20	24	0	10	0	0	1	10
1997	275	3327	938	57	32	1	0	5	1	0	2	1
1998	598	4040	843	93	16	51	0	5	1	5	2	0
1999	957	5898	1462	86	10	113	0	0	3	260	0	0
2000	720	5903	1318	939	4	0	0	16	1	66	1	0
Totals	5 722	28 141	6 168	1 277	449	215	1	48	10	336	8	11

[a] NTPK is northern pike (*Esox lucius*), WHSC white sucker (*Catostomus commersoni)*, LKWH lake whitefish (*Coregonus clupeaformis)*, RBTR rainbow trout (*Oncorhynchus mykiss)*, BURB burbot (*Lota lota*), BKTR brook trout (*Salvelinus fontinalis)*, ATSL Atlantic salmon (*Salmo salar*), GOLD goldeye (*Hiodon alosoides*), MOON mooneye (*H. tergisus)*, SAUG sauger (S. canadense), YLPR yellow perch (*Perca flavescens)*.

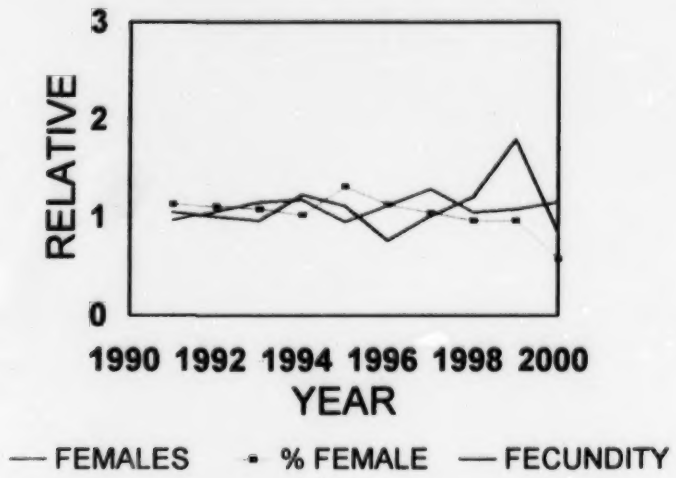

Figure 3. Trend in indicators of walleye status from hatchery records, 1991 to 2000.

Linear regressions against years 1991 to 2000 show a tendency for increasing numbers of females caught and spawned, numbers of eggs collected, and fecundity (average eggs per female) (Table 3). None of these slopes over time are statistically significant (see Prob > 0.05), although the increase in number of eggs and the decrease in female percentages in catches would be significant with a lower 90 % confidence. However, there are problems with emphasizing any increases or decreases. First, simple linear regression is contra-indicated for data that are clearly a time series. Second, as more time series or regressions are tested, there is an increasing chance that significant trends will be falsely flagged. For several comparisons, a suitable significance level should be chosen and then used to adjust the criterion for each test.

Table 3. Indicators from hatchery operations in Coteau Bay, 1991 to 2000.

Indicator	Average ± 95% CI [a]	Linear regression (Indicator versus Year)			Years outside CI of regression	
		r^2 (%)	Slope	Prob [b]	Low	High
Females caught	1557.8 ± 323.4	5	31.61	0.57	1996	1999
Females spawned	670.0 + 98.3	23	20.83	0.19	...	1995
Eggs collected (millions) [c]	95.4 ± 12.8	44	3.75	0.0534	...	1995 1997?
Fecundity per female (thousands)	142.8 ± 10.4	9	1.42	0.42	1995	1997
Females [d] (as % of catch)	41.4 ± 6.3	44	-1.84	0.0532	2000	1995
Hatch rate (% of eggs)	50.1 ± 7.5	33	1.91	0.11	1991	1993 1994

[a] Confidence interval for calculated average

[b] Probability of slope being different from zero (Prob < 0.05 would mean a significant trend up or down).

[c] Polynomial regression is much more suitable since eggs peaked in 1995.

[d] Time-series auto-correlations and partial auto-correlations are all non-significant over 1 to 5 years.

Time series analysis of the proportion of females showed a tendency for the percentage to be positively related to one or two years earlier, and negatively to four or five years earlier (Figure 4). This is statistically non-significant for all auto-correlations (bars within confidence lines) (NWP 1998). Nonetheless, this indicator deserves watching for biological reasons. High percentages showing for one to three years may be a strong year-class passing through; high percentages followed by low percentages about four or five years later may indicate a downward trend or simply natural fluctuations. The fitted linear regression shows that all individual years lie withing the confidence lines and prediction band, but that 2000 is quite low (Figure 5). Statistically, the percentage for 2000 is also below the cutoff for "studentized residuals," which are the differences between each observation and the regression line after adjusting for variation.

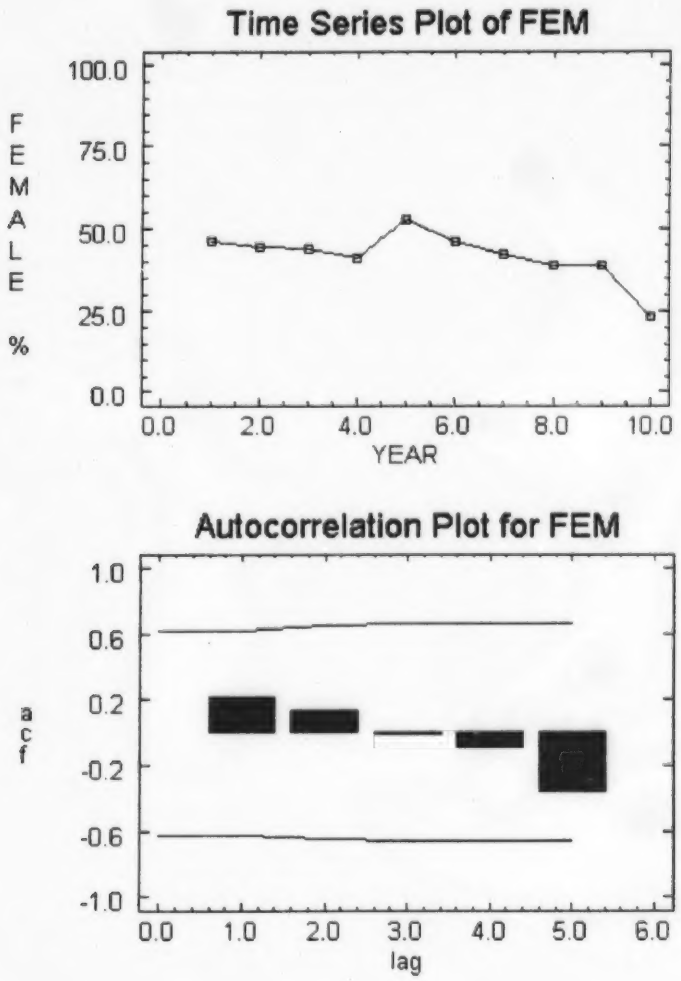

Figure 4. Time series of proportion of females (as % of catch) in Coteau Bay, 1991 to 2000.

UPPER graph shows time series, with missing 1992 estimated as average of 1991 and 1993. LOWER graph shows auto-correlations with percentage from one to five years prior (bars) and confidence limits for significance (lines); bars between the lines are non-significant.

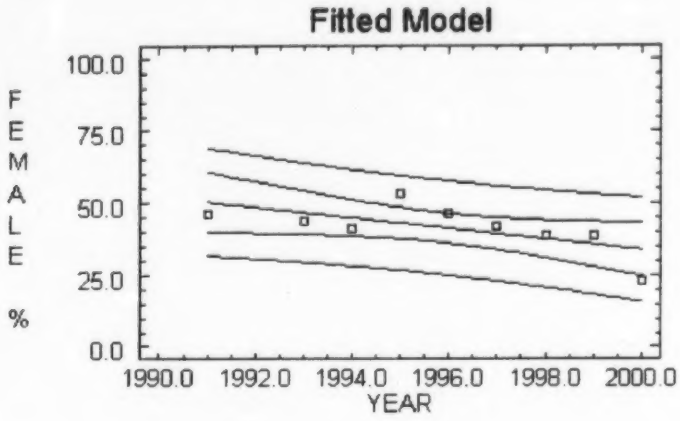

Figure 5. Regression of proportion of females (as % of catch) in Coteau Bay, 1991 to 2000.

The graph shows confidence limits for 95 % of many points (inner lines) and prediction band for a single point (outer lines).

Catches do not vary widely from year to year (Table 4) and may not reflect abundances reliably, because the focus is on obtaining sufficient numbers of good quality eggs. Staff adjust their fishing to maintain catches, but there is an upper limit on the daily number of eggs that can be collected, fertilized, and tended before shipment.

Table 4. Number of walleye caught during spawn camp, 1998 to 2000 [a].

Year	Number of walleye	Number of days
1998	4 669	13
1999	5 667	17
2000	5 619	15

[a] numbers include the many walleye which are re caught one or more times.

3.2 SIZES AND AGES

About 10,000 walleye were measured in the three years. About two-thirds of those measured were males because they are typically more common than females among spawners.

Females were noticeably larger than males in all years (Figure 6). This difference was statistically significant in all years (pairwise two-sample $p = 0.05$).

Sizes of each sex varied slightly from year to year, especially in 1999 (due to a snow storm on day 12 of spawning operations). There may be real changes from year to year, but these are likely only normal fluctuations due to new year-classes.

During 1998, females averaged 55.0 cm fork length, with an estimated average weight of 2.29 kg (5 pounds). Sizes were larger in 1999 at 58.9 cm (2.82 kg or 6.2 pounds), but similar again in 2000 (Table 5).

Spawners in Coteau Bay are substantially larger than walleye in angler catches, according to creel surveys in 1983 and tournament walleye measured at the Riverhurst Walleye Classic in 1998. The length of spawners averaged 41.6 cm and angled fish only 29.8 cm in 1983. This was about 14 years after initial walleye stocking, so there may have been limited numbers of old-aged walleye. By 1998, the differences are less noticeable because the minimum lengths are similar, that is, tournament anglers release small walleye (Table 6). The minor overlap of sizes in 1983 was one reason that we did not design our survey to use angled walleye in mark-recapture estimates.

Age materials were available for 124 female and 71 male walleye from summer surveys in 1992 and 1995 (Jennifer Merkowsky pers comm; Ron Jensen unpubl data) and 25 female necropsy specimens from 1998 (Cam Portt pers comm). These provided age-length keys for known females and males separately, which should be applied only with caution to fork-length compositions of other years (Ricker 1975) (Appendix 3 and 4).

Age compositions showed walleye in Coteau Bay range from four to 20 years old. Females appeared to fully mature at age six and reached 20 years, while males arrived at age five and reached 15 years. On average, about 14.9 % of females are age six and about 19.2 % of males are age five. About seven % of females were 18 years or older (Figure 7). The obvious variations in year-classes (such as low numbers of ages seven, eight and 10) are believed to be artefacts of the use of ages from other sources and previous years population surveys. Non-lethal ageing material was not collected directly from the spawning population during this study.

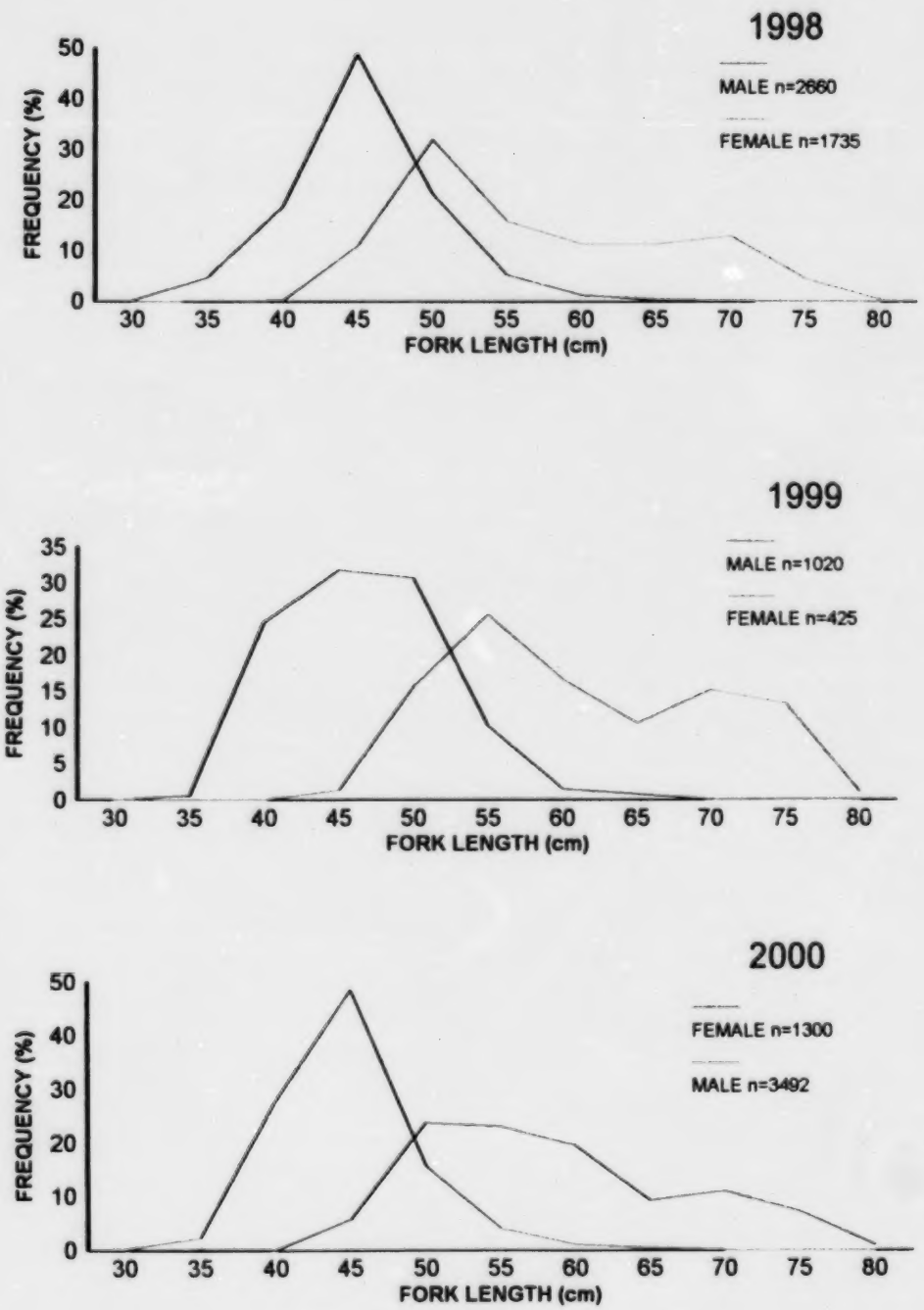

Figure 6. **Fork lengths of female and male walleye measured in Coteau Bay 1998 to 2000.**

Table 5. Fork lengths of walleye in Coteau Bay spawning 1998 to 2000.

Year	Females Number	Average	Range	Males Number	Average	Range
		(cm)	(cm)		(cm)	(cm)
1998	(1,735)	55.0	35 to 76	(2,660)	43.5	23 to 67
1999	(425)	58.9	43 to 77	(1,020)	44.4	31 to 64
2000	(1,300)	57.7	35 to 77	(3,492)	43.5	14 to 71

Table 6. Walleye fork lengths for spawning areas and caught by anglers, 1983 and 1998.

Year	Spawners Number	Average	Range	Angled Number	Average	Range
		(cm)	(cm)		(cm)	(cm)
1983 [a]	(227)	41.6	31 to 50	(60)	29.8	21 to 45
1998 [b]	(4,395)	48.1	31 to 77	(273)	39.3	31 to 68

[a] Data for 1983 angling and spawners are from Chen (1983).

[b] Averages for spawners in 1998 and 1999 are weighted by the observed female to male sex ratios of 1:1.5 males and 1:1.6, respectively (Greg Mitchell pers comm). Data for 1998 angling are from walleye tagged at Riverhurst tournament in June (Table 7). The comparison of tournament angler catch to spawning walleye may unfair because the walleye at Riverhurst tournament in 1998 were small. This smallness of the tournament catch is demonstrated by the average weight for all tournament fish weighed for the three years of the study.

Table 7. Average weight(g) for fish kept at Riverhurst Walleye Tournament 1998 - 2000.

Year	Average Weight (g)
1998	653
1999	830
2000	712

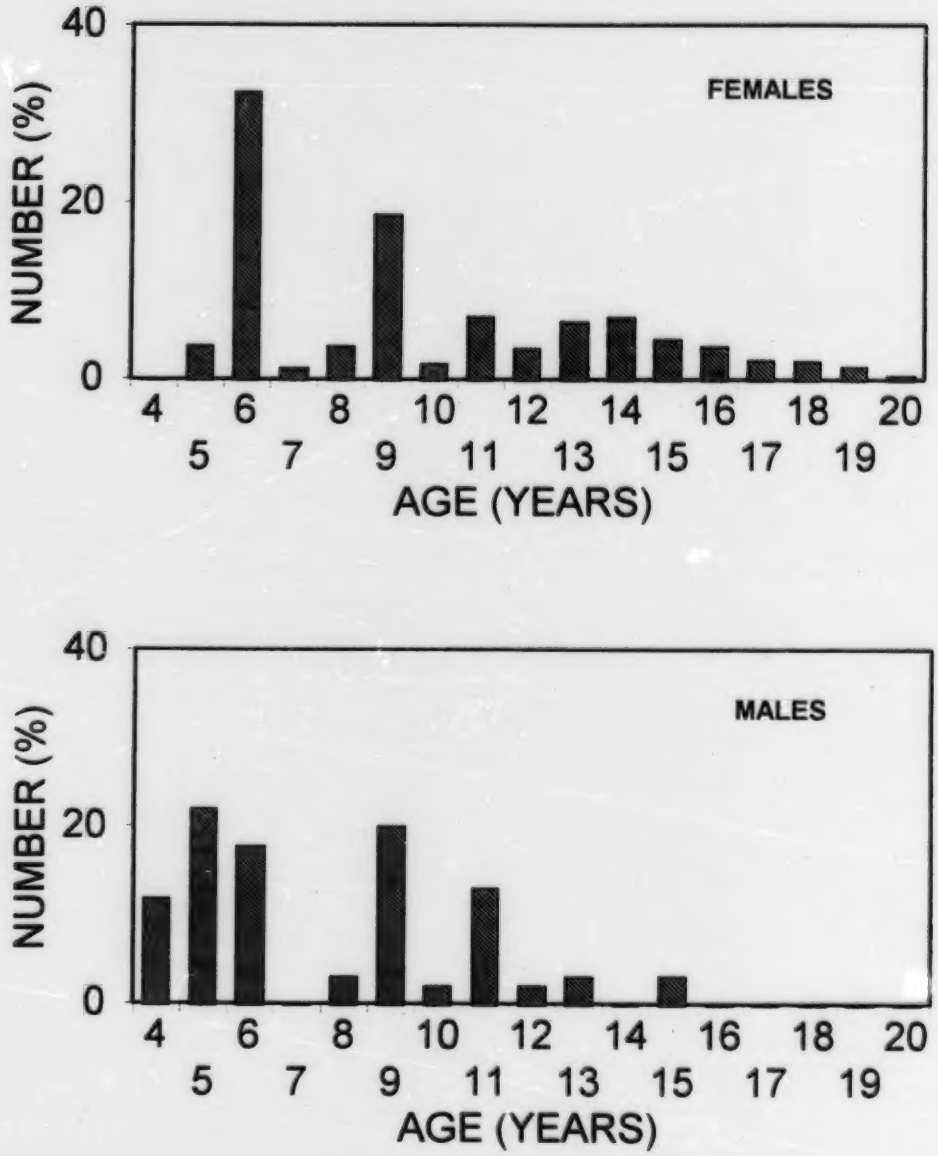

Figure 7. Age composition of female and male walleye in Coteau Bay in 1998.

This is based on fork lengths in 1998 and a composite age-length key from various surveys in 1992, 1995, and 1998.

Annual mortality rate for female walleye in Coteau Bay in 1998 was 13.1 % for ages six to 20. This was calculated in the usual way from "catch curves" (Ricker 1975):

Log (Number) = 2.59 - 0.061 Age, with n = 15, $r^2 = 0.33$, SE(Slope) = 0.0243
and Z = Ln(-Slope) = 0.141 and annual mortality A = 1- Exp(-Z) = 0.131

Annual mortality rate for males in 1998 was 18.5 % for ages five to 15:

Log (Number) = 3.06 - 0.089 Age, with n = 9, $r^2 = 0.41$, SE(Slope) = 0.0399
and Z = Ln(-Slope) = 0.205 and annual mortality A = 1- Exp(-Z) = 0.185

These numbers are approximate at best because only a few ages for walleye were available from Coteau Bay in 1998 (Cam Portt pers comm), and from surveys in other areas of Lake Diefenbaker during 1992 and 1995 (Al Merkowsky, Ron Jensen, Jennifer Merkowsky unpubl data). Use of age-length keys from one year to another, or from different sample seasons, areas, or gear is not recommended (Ricker 1975). In addition, data for both mature and immature males were included in the key yet there were no ages suitable for six to seven % of (larger) males. On the other hand, our main interest is the mortality rate. The lack of olad age males would not be seriously affected the mortality rates.

3.3 TAGGING

From the first day, it was obvious that the metal-tags did not perform according to past experiences with their use on other species (Ron Jensen and Peter Ashcroft pers. obs.). The tags were a new aluminum material, rather than the former "monel" which had been successful. They were not snugging down securely on the operculum, but were checked to ensure that every tag was clinched as well as possible. Without alternative tags, the dorsal punches became even more important.

Coteau Bay

In total over the three years of study (Table 8), about 11,300 walleye were marked for later identification. In 1998 at Coteau Bay, about 1,000 walleye received serial numbered metal tags alone (MT), about 2,000 were double-tagged (MT & DP), and about 1,000 were only dorsal punches (DP). In subsequent years, 1999 and 2000, a hole was punched into the caudal fin (CP) and left pelvic fin (PP) respectively. Walleye were marked only once in any given year to account for recapture of the same individual fish within that spawning year. The marks were used to determine presence/absence in subsequent years of the study. These numbers include only newly marked fish. Others had already been tagged in previous years, and some were recaptured within the present year.

Different numbers of fish were analyzed for different purposes. Size compositions used only one measurement per fish and ignored within-year recaptures. Some estimates of within-year abundance depended on the complete recapture history of every fish (e.g. Jolly-Seber, below).

Table 8. Number of walleye marked in each year and recaptured from previous years.

Yea	Dates	Seen	New	Marks applied			Recaptured from year		
				First	Second	Both	1998	1999	1998 & 1999
Coteau Bay tags[a]:									
1998	Apr 26 to May 07	4,395	4,394	1,054 MT	1,239 DP	2,019 MT&DP	...	...	...
1999	Apr 29 to May 13	4,578	3,472	3,472 CP	...	...	1,106	...	...
2000	Apr 29 to May 07	4,792	3,496	3,496 PP	...	...	435	708	249
Riverhurst tags[b]:									
1998	June 20 to 21	374	274	274 MT	...	...			...

[a] Metal tags were silver with serial numbers 0001 to 9999 at Coteau Bay and red with serial numbers 10000 to 15000 at Riverhurst.
[b] Only 6 were recaptured in Coteau Bay in 1999 and 2000, although more were recaptured at other locations (see Angling below).

In both 1999 and 2000, about 75 % of the walleye in Coteau Bay were considered 'new fish.' This includes first-time spawners, repeat spawners on their first visit to Coteau Bay, and repeat visitors which were not previously caught (Figure 8). A substantial number of walleye were caught in Coteau Bay in all three years and would be considered "faithful" spawners.

Riverhurst

In the tournament on June 20 - 21, 1998 at Rusty's Marina only 374 fish (walleye, sauger and walleye-sauger hybrids) were caught by tournament anglers. Of these, 274 walleye seemed large enough to spawn in 1999 and were tagged.

3.4 ABUNDANCE

Several adjustments to numbers of tags were necessary to account for tag loss, recruitment of first-time spawners, and arrival times.

Tag loss - Tag losses from fish were estimated only for metal gill cover tags. The variation of double-tagging using permanent marking of fish (Robson and Regier 1964) was based on dorsal punches (DP) and metal tags (MT) applied to the same fish. Dorsal punches were considered permanent since they showed: a clear hole, an obvious pattern of regrowth, or partially missing in the fifth ray of the spiny dorsal fin. Metal tags that were lost left obvious holes or scarring of the operculum. Other marks (such as caudal and pelvic fin punches) were intended for use only within each year, and showed ambiguous scars or even regrew.

The metal tags used in 1998 certainly affected the walleye. Fish that received a metal-tag (alone or with DP) in 1998 were recaptured less often in 1999 than expected by the original proportions tagged. This was shown by the significant statistical differences between observed numbers of recaptures compared to expected numbers of recaptures (Table 9).

Table 9. Observed versus expected tagged walleye returns to Coteau Bay spawn camp, 1999[a].

Tag Type	Observed	Expected
MT only	241	266
DP only	382	312
MT & DP	483	528

[a] metal tags reduced the number of observed recapture and the dorsal punch did not.

Overall chi-square = 21.9, which means $p < 0.001$ and one or more difference is significant.
Pairwise (MT versus DP) chi-square = 13.7 and $p < 0.001$ and significant;
pairwise (MT versus DP&MT) chi-square = 0.01 and $p < 0.95$ and not significant;
pairwise (DP versus DP&MT) chi-square = 27.9 and $p < 0.001$ and significant.

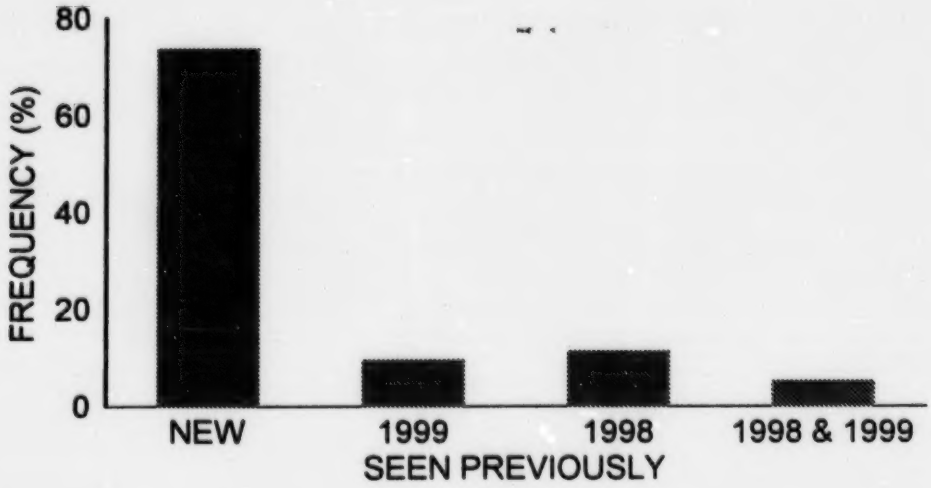

Figure 8. Number of walleye caught in 2000 which were new or seen in previous years.

"New" fish in figure 8 includes first-time spawners, first-time visitors to Coteau Bay, and those simply not caught previously; "1999" represents fish caught in that year; "1989" represents fish caught in that year; "1998 & 1999" represents fish caught in both 1998 and 1999 in Coteau Bay.

The potential reasons for this effect include:
(1) metal-tags reduce the chance of walleye being recaptured, such as by lowering survival,
(2) observers misclassified some marks, such as natural scars being called DP, and/or
(3) groups of walleye were different before being tagged, or were handled differently during tagging or afterwards (Don McKinnon pers comm).

The rate of metal-tag loss was estimated from numbers of recaptures in 1999 and 2000 of fish with signs of dorsal-punch (DP) and metal-tag (MT) initial marks (Table 10).

These data indicate tag retention was 40 % during the first year and 31 % over two years (Seber 1973). This implies that retention was lower in the first year and higher in the second for the tags which remained, about 40 % and 78 % respectively. Tags that were loose and dangling, or close to the edge of the gill cover, may have worn rapidly through in the first year and left fewer like them to wear through in the second year.

Another common way to estimate tag-loss combines marking in one year and recaptures for the next two years. This uses all available data (Seber 1973): $m_1 = 483$, $b_1 = 192$, $m_2 = 321418$, $b_2 = 99129$, and shows our average retention for metal tags (r-hat) = 0.4841 per year. This implies that retention would be 48 % after one year and 23 % after two years, if the loss rate is constant each year.

Table 10. Number of walleye with dorsal-punch and metal-tag marks.

	Number of fish with DP and		
	MT kept	**MT lost**	**MT total**
Year recaptured:			
1999	192	291	483
2000	129	289	418
Sex:			
Females in 1999	56	93	149
Males in 1999	136	198	334
Females in 2000	28	75	103
Males in 2000	71	147	218

Table 10 provides data for tag retention rates for females and males separately for 1999 when sample sizes were sufficient. Retention was similar for both sexes, at 38 % for females and 41 % for males after one year.

Punches were not intended as permanent marks. Caudal punches (CP) appeared to regrow week-to-week although minor hemorrhage or inflammation remained visible, pelvic punches (PP) regrew from year to year and were only detectable by feel due to fleshiness of fins (Peter Ashcroft pers. comm.).

Recruitment

About 15 % of females and 19 % of males may be first-time spawners. This is based on the proportion of six-year-old females and five-year-old males predicted by age compositions (see above). These are only approximate because maturity occurs over a range of size and age, year-classes are usually variable, and age compositions for Coteau Bay are extrapolated from open-lake specimens.

Order of arrival

Walleye were still present when spawn camp closed at Coteau Bay on May 7 in 1998. Daily catches of unripened "green" females suggested more were arriving. This implies that those walleye tagged arrived earlier in the run. By comparing dates of recapture in 1999 and 2000 for tagged walleye against order tagged in 1998, it is possible to infer a preference for arrival timing in spawning run.

There was a significant statistical tendency for fish that arrived earlier in 1998 to also arrive

earlier in 1999:

Tag# = 1083.6 + 44.72 (Day in 1999),
where n = 272 recaptures, $r^2 = 0.04$ ® = 0.20), SE(slope) = 13.31, $p < 0.05$

There was a smaller and non-significant time-of-arrival effect even two years later:

Tag# = 1306.0 + 26.74 (Day in 2000),
where n = 193 recaptures, $r^2 = 0.007$ ® = 0.08), SE(slope) = 23.23, $p > 0.05$

Since early arrivals do not mix randomly with late arrivals, their recapture will be concentrated in the early portion of the run. No feasible correction for this factor was determined so the estimate represents mostly this early portion and will be too low for the entire population.

Biologically, behavioural differences were not surprising since, for example, male walleye often arrive earlier than females. The effect was not apparent in 2000, either because the fish had drifted off any schedule or because recaptures were too few to be conclusive.

Length of stay

For within-year estimates, the number of individual spawners could only be found if the number of walleye-days is divided by the average residence time of fish. The only measure of residence came from fish that were tagged and later recaptured. Direct methods such as radio-tracking individuals might be better, but would bring their own problems of few samples and high costs and still cut observations short when crews left.

Some fish were recaptured the next day after being tagged and not again, and some were recaptured up to 10 days after tagging. The average length of known stay (Table 11) ranged from 6.37 days down to 4.65 days for those tagged later.

Table 11. Average length of stay for spawning walleye at Coteau Bay, 1998.

Day of tagging	Known stay (days) [a]
1st	6.37
2nd	6.12
3rd	5.80
4th	5.38
5th	4.65

[a] based on recapture of individual walleye during 1998 spawn camp.

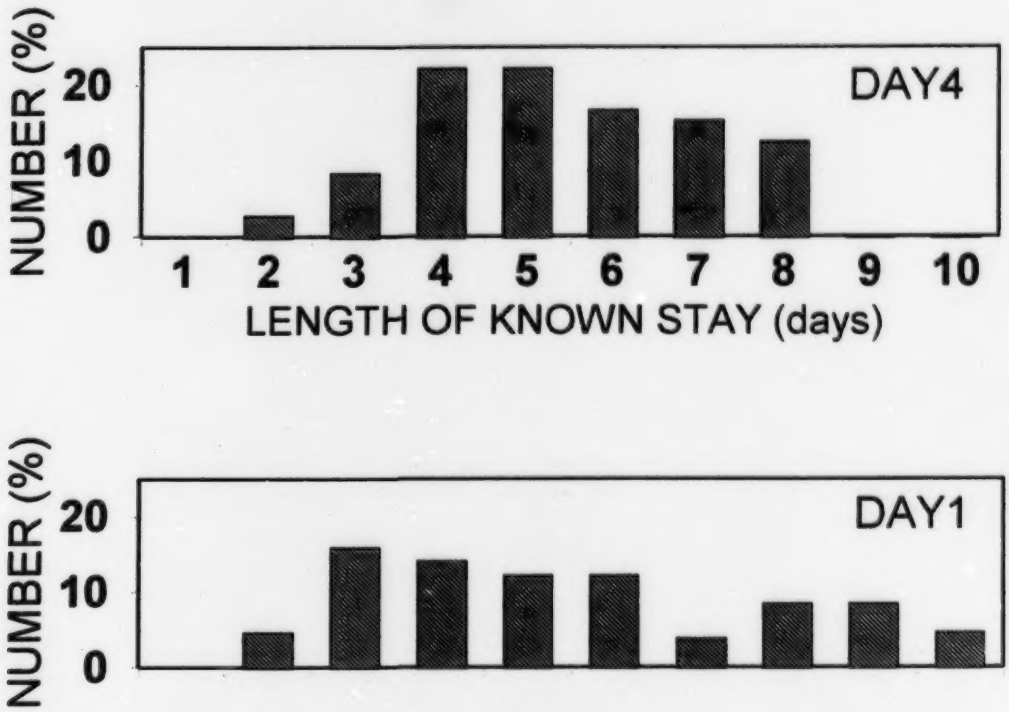

Figure 9. Length of known stay of individual walleye in Coteau Bay, 1998.

These examples show fish tagged on day one and day four of survey.

The decline in length-of-stay is almost certainly due to lack of data on later arrivals which probably remained after crews left. For this reason, fish tagged after day five were not analyzed because this seemed too close to the end of survey on day 11. Fishing effort was relatively constant and the proportion of fish caught only once increased smoothly during the survey. Likewise, fish caught only once were excluded because it seemed much more likely that they were present but not caught again than that they only stayed one day (peaks at three to five days, Figure 9).

The best estimate of average is about six days, assuming that arrivals on days one to three are representative of sex, size, and residence.

According to the two kinds of analysis based on daily mark-recaptures, the "open" population in Coteau Bay has about 3,000 to 8,000 walleye present in early days. This reaches at least 40,000 walleye by day seven or eight (Table 12). The Schnabel analysis based on sequential three-day mark-recapture periods is an *ad hoc* attempt to minimize the effects of immigration and emigration by shortening time periods. The formal Jolly-Seber method has been developed by statisticians in recent decades to allow for these complications (Pollock et al. 1990).

The number of individual walleye in Coteau Bay at some time during spawning in 1998 is estimated at 36,000 to 57,000 by the two within-year methods. It is believed that these within-year estimates of abundance are too high, because the number of recaptures is artificially low. Many walleye (especially females) were held up to three days before release, which delayed the return of tagged fish into the population. Secondly, most walleye were released at spawn camp (at least 1 km from some trap-nets) and the chances of immediate recapture were low for a day or so. Both of these problems would affect the Schnabel method, which uses data from tagging days and the following two days. The Jolly-Seber method was also affected because it does not generally allow for temporary absence of tagged fish, only permanent emigration or immigration is allowed. Statistical goodness-of-fit tests also showed that a Jolly-Seber analysis was only suitable under restricted conditions (see Table 12 footnotes).

The spawning population in Coteau Bay comprised about 15,000 walleye in 1998 and 11,000 to 22,000 walleye in 1999, based on year-to-year marks and recaptures (Table 13). Between 4,000 and 6,000 of these are females and between 6,000 and 16,000 are males. Data on DP-alone indicated about 12,000 in 1998 and only 9,000 in 1999. Data for caudal punches indicated higher abundance than MT and DP combined. If some losses of CP marks were undetectable year-to-year, rather than negligible as assumed, then their estimate of 22,000 would be too high. Adjustments for tag loss and recruitment should have minimized most other biases (Ricker 1975).

Table 12. Estimates of daily walleye abundance in Coteau Bay, 1998 [a].

	Schnabel method [b]			Jolly-Seber method [b]		
	Number	Confidence interval		Number	Confidence interval	
Day	present	Lower	Upper	present	Lower	Upper
1	...	...	...	...	...	...
2	2,627	1,959	3,718	4,142	946	7,339
3	8,224	5,438	12,831	7,432	129	14,735
4	6,560	4,690	9,859	...	...	...
5	22,509	14,884	35,123	16,769	9,082	24,457
6	12,789	9,274	18,587	18,225	13,514	22,937
7	23,931	18,010	33,318	49,833	10,494	89,172
8	41,950	27,998	68,911	92,132	0	195,768
9	46,359	31,213	73,814	...	...	...
10	50,557	30,805	85,511	...	...	...
11	...	...	...	...	...	...
Totals [c]	215,506	...	...	340,902	...	...
Individuals	35,917			56,817		

[a] These methods use daily mark-recapture data for within-year estimates.

[b] Schnabel uses three-day mark-recapture data (Krebs 1997); Jolly-Seber method shows acceptable fit to two periods (days 1 to 4 using birth-and-death model A, and days 5 to 9 using death-only model A', see JOLLY program of Pollock et al. 1990).

[c] Totals represent number of walleye-days over days two to 10; totals for Jolly-Seber used averages of neighbouring days if necessary. Totals were converted to numbers of individuals using average length-of-stay.

Table 13. Estimates of seasonal walleye abundance in Coteau Bay, 1998.[a]

	Females		Males	
Number	**Metal tag [b]**	**DP alone**	**Metal tag [b]**	**DP alone**
Marked in 1998	1,223	512	1,932	728
Recaptured in 1999	80	147	198	235
(Retention rate)	38%	100%	41%	100%
Corrected recaps	211	147	483	235
Examined in 1999	1,406		3,172	
(Recruitment)	15%		19%	
Corrected exams	1,195		2,569	
Summary:				
Total marked	1,735		2,660	
Total recaptured	358		718	
Total examined	1,195		2,569	
Abundance in 1998	5,783		9,512	

[a] This method adjusts for several factors to obtain year-to-year estimates.

[b] Number of metal tags alone (MT) or MT with DP.

Table 14. Estimates of seasonal walleye abundance in Coteau Bay, 1999. [a]

	Females		Males		CP alone	
Number	**MT** [b]	**DP**	**MT** [b]	**DP**	**Females**	**Males**
Marked in 1998	1,223	512	1,932	728	... [c]	... [c]
(Survival rate) [d]	86%	86%	82%	82%	...	...
Corrected marks	1,052	440	1,584	597	1,033	2,439
Recaptured in 2000	184	127	424	277	188	404
(Retention 2nd year)[d]	78%	100%	78%	100%	100%	100%
Corrected recaps	**236**	**127**	**544**	**277**	188	404
Examined in 2000	1,490		4,125		1,490	4,125
(Recruitment 2 yrs) [d]	28%		35%		28%	35%
Corrected exams	1,073		2,681		1,073	2,681
Summary:						
Total marked	1,492		2,181		1,033	2,439
Total recaptured	363		821		188	404
Total examined	1,073		2,681		1,073	2,681
Abundance in 1999	4,405		7,119		5,876	16,158

[a] This method adjusts for several factors to obtain year-to-year estimates.

[b] MT (metal tags alone or MT with DP) and DP alone are from initial tagging in 1998.

[c] 'CP alone' was applied in 1999, so needs no correction from 1998 .

[d] MT and DP were corrected for survival, tag loss in the second year, and recruitment over two years.

3.5 ANGLING

All three catch-and-release tournaments (at Elbow, Riverhurst, and Sask Landing) were attended by staff each summer between 1998 and 2000 to record catches and follow walleye movements. The catch-and-keep derbies (between two and five each summer, each with 20 to 100 anglers) were not attended.

Anglers commented that posters and the human contact on the toll-free phone line were important and encouraged them to report recaptures throughout the season.

Recaptures were reported from early May to late December (Table 15). Early recaptures were primarily from the Coteau Bay area in 1998. Later reports were usually further up the lake (probably due to walleye movements and changes in angling patterns). Angling reports showed walleye within 40 km of Coteau Bay in May, and 146 km up the lake at Beaver Flats by early September (Figure 10). In subsequent years, 1999 and 2000, there were reports of tagged walleye remaining in Coteau Bay. Four tagged walleye, one in 1998 and three in 1999, were caught below the spillway of Gardiner Dam. The emergency spillway had conveyed water around the dam in spring of 1998.

In three years, 342 reports of recaptures were made by tournament and recreational anglers. Numbers declined over time for a variety of factors (death of walleye, loss of tags, dispersal of walleye to other areas, and perhaps less interest among anglers).

Table 15. Locations of first and last dates of reported recaptures, 1998 to 2000.

		First report		Last report	
Year	**Number of reports**	**Date**	**Location**	**Date**	**Location**
1998	176	May 28	Coteau Bay	Sep 05	Beaver Flats
1999	78	May 08	Coteau Bay	Dec 28	Belhmur Bay (Riverhurst area)
2000	27	May 06	Big Fill (Atikow Creek)	Aug 17	Gardiner Dam (spillway channel)

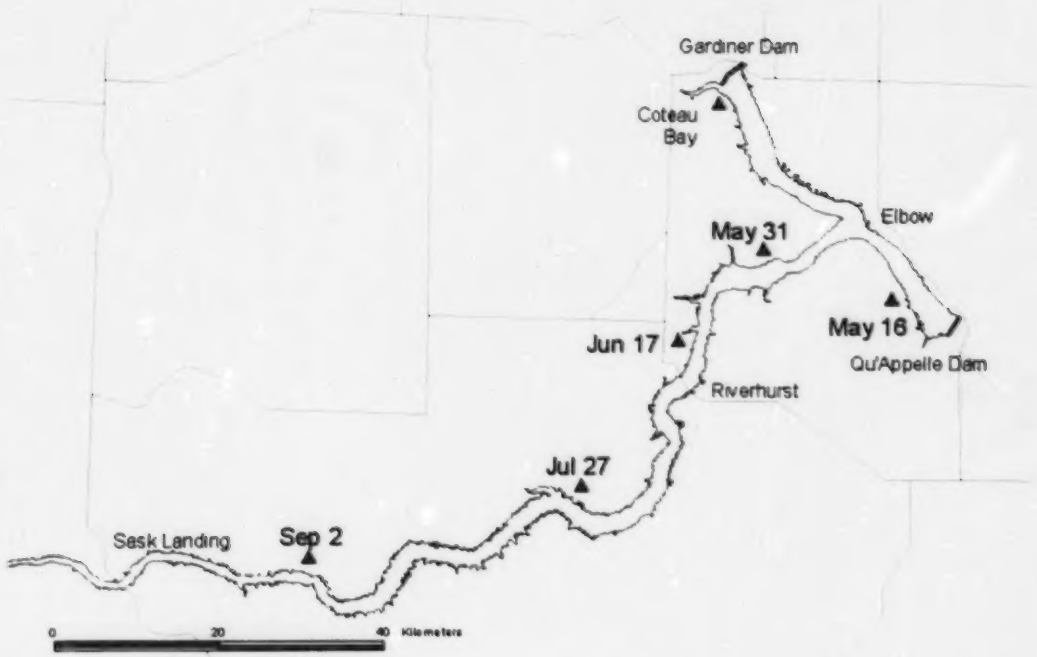

Figure 10. Representative dates and locations of recaptured walleye from Coteau Bay, 1998.

A total of 195 recaptures were observed at the three tournaments, with a high of 124 at Elbow within a month of initial tagging in Coteau Bay (Table 16).

The Elbow tournament (Lake Diefenbaker Walleye Classic) ran in late May with 101 to 118 teams of two anglers weighing-in up to 10 walleye. Rules allowed angling throughout the entire lake for two days with daily cutoff times. On the second day of the tournament, boats tend to gather where fishing had been good on day one. In 1998, about half of the boats (56 of 118) were observed in Coteau Bay on day two, and almost all reports of tagged walleye (48 of 53) came from this area that day. Over two days in 1998, 93 % of observed recaptures (115 of 124) came from Coteau Bay. Tournament boat numbers in Coteau Bay remained similar in 1999 and 2000 but tag returns fell. In 1999, half of the returns (21 of 38) came from Coteau Bay and in 2000, only five tagged walleye were caught.

Many walleye had not left the Coteau Bay area in 1998 before recapture, especially in the first month after tagging. About 11 % of walleye weighed-in at Elbow in 1998 had tags from Coteau Bay. If angling was more concentrated in this area than walleye were, then recaptures would be over-emphasized. The relative concentrations are unknown and angling reports may actually reflect walleye density. Later in the season, a few recaptures in this bay showed that some walleye obviously remain for months.

Tournament anglers from Elbow caught about four per cent of all tagged walleye in this area at the end of May 1998. These were all released at the Elbow marina, causing either displacement of these walleye or some "assistance" in their intended direction.

The Riverhurst Walleye Classic tournament ran on Father's Day weekends in June. Participation ranged from 99 to 107 teams of two people and between 374 and 935 walleye were weighed-in each year. In 1999, about 21 % of fish were sauger or sauger/walleye hybrids (36 of 170 fish). Fishing was restricted to a 32-km long section centred on the Riverhurst ferry. This eliminated recaptures from Coteau Bay. Far fewer returns were observed at this tournament, although their decline over three years was also lower.

The latest of the annual walleye tournaments on Lake Diefenbaker is the "Saskatchewan Landing Walleye Tournament" in late July with between 109 and 114 teams of two anglers. In 1999, tournament anglers weighed-in 686 fish. This tournament occurs in a 65-km long section of the lake at the upstream end, with boundaries between Cabri and Herbert Regional Parks. Rules permit weighing-in walleye, sauger, or sauger/walleye hybrids. No estimate of species combination was recorded for this tournament. Over the three years, only one tagged walleye was reported from near the Herbert Regional Park boundary.

Including the tournaments, 62 reports of recaptures had unknown date or location. Reported locations required some investigation because of the use of several local names for the same site, and some use of the same name for different sites (such as Pumphouse Bay). Local names may not necessarily correspond to names on two privately published maps of the lake.

Table 16. Recaptures of walleye at catch and release tournaments 1998 to 2000 [a].

Tournament Year	Dates	Number	Locations
Elbow:			
1998	May 30 - 31	124	115 in Coteau Bay; also Qu'Appelle Arm, Birsay
1999	May 28 - 30	38	22 in Coteau Bay; also Big Fill, Fords, Sage
2000	May 27- 28	5	3 in Coteau Bay; Fords Coulee (Summit Creek)
Riverhurst:			
1998	Jun 21 - 22	10	Cactus Bay, Hamilton's coulee
1999	Jun 19 - 20	10	Cactus Bay, Hitchcock Bay
2000	Jun 17 - 18	7	Cactus Bay, Birsay Bay
Sask Landing:			
1998	July 25 - 26	0	...
1999	July 24 - 25	0	...
2000	July 28 - 29	1	Bear's Paw

[a] Walleye tagged at either Coteau Bay or Riverhurst in 1998 are included.

Twelve walleye (about 0.3 % of reports) were recaptured more than once (Table 17). Ten of these were caught first by anglers at the Lake Diefenbaker Walleye Classic and released to be caught again. The longest time between recaptures by anglers was eight months, during which this walleye moved 121 km from Elbow marina to Beaver Flats cottage subdivision.

Two walleye were each caught three times by separate fishermen. Walleye #905 was caught three times between the Gardiner and Qu'Appelle Dams (a 40-km stretch) but no dates were reported. Walleye #1686 was reported caught once each year from Coteau Bay, Riverhurst tournament, and Ford's Coulee (Summit Creek), respectively. At the very least, this walleye covered 36 km between release site at Elbow tournament and Riverhurst tournament between 1998 and 1999. It returned 19 km to Ford's Coulee before the 2000 Lake Diefenbaker Walleye Classic and was weighed-in at Elbow for its second time in three years at a tournament.

There were two examples of walleye moving to Coteau Bay for spawning. They were caught by tournament anglers in 1998 and released at Elbow, then recaptured in Coteau Bay the following spawning season.

Table 17. Multiple recaptures of walleye by anglers, 1998 to 2000 [a].

Tag number	Recaptures		Travel (km)	
	Date	Location	Distance	Days
693	May 31 1998	Coteau Bay	0	...
	January 31 1999	Beaver Flats	121	242
842	May 31 1998	Coteau Bay	0	...
	.....	Below Gardiner Dam	1	...
905	.....	Gardiner Dam	3	...
	.....	Qu'Appelle Dam	35	...
	.....	Atikow Creek	3	...
1072 [b]	May 31 1998	Coteau Bay	0	...
	July 17 1998	Mistusinne subdivision	5	47
1461 [c]	May 31 1998	Coteau Bay	0	...
	August 2 1999	Coteau Bay	26	428
1581	September 2 1998	Beaver Flats	121	125
	September 5 1998	Beaver Flats	0	3
1686	May 31 1998	Coteau Bay	0	...
	June 19 1999	Riverhurst tournament	62	384
	May 27 2000	Ford's Coulee(Summit Creek)	54	321
2004	May 31 1998	Coteau Bay	0	...
	August 19 1998	Big Fill (Atikow Creek)	19	80
2165	May 31 1998	Coteau Bay	0	...
	.....	Hitchcock Bay	19	...
2352	May 31 1998	Coteau Bay	0	...
	May 31 1998	Douglas Park	10	62
2779	May 29 1998	Coteau Bay	0	...
	May 31 1998	Coteau Bay	0	...
2974	May 31 1998	Coteau Bay	0	...
	June 19 1999	Riverhurst tournament	62	384
10213	May 15 2000	Cactus Bay	8	1056
	July 8 2000	Pumphouse Bay (Riverhurst)	2	54

[a] Walleye were initially tagged at either Coteau Bay or Riverhurst.

[b] Walleye "1072" was caught at spawn camp in May 2000, then twice by anglers in 1998.

[c] Walleye "1461" was caught and displaced during the 1998 Elbow tournament, caught at spawn camp in May 1999, and angled in August 1999, all in Coteau Bay.

The time between tagging at Coteau Bay and later recapture ranged from 22 to 125 days for first catch by anglers and three to 428 days for the second recapture. One walleye number 10213 was tagged at Riverhurst in 1998, was caught in 2000 (1,056 days later) and caught again 54 days later by a second angler all within 10 km of Riverhurst. At least one walleye demonstrates an affinity for the Riverhurst area.

3.6 MOVEMENTS

Generally, reports of recaptures suggest that walleye reached as far as reported in Table 18.

Table 18. Location and month of recapture of tagged walleye in 1998. [a]

Location on Lake Diefenbaker	Month of Recapture
Qu'Appelle Dam	mid May
Birsay/Sage Bay	mid May
Riverhurst	mid June
Snakebite Coulee	late July
Beaver Flats	early September

[a] Walleye tagged at Coteau Bay and Riverhurst

A few walleye moved 150 km up the lake within four months in 1998 (Table 19). The furthest movement was 166 km by September 1998 (Figure 11). In 1999 (Table 20), numbers of recaptures were smaller and typical distances were correspondingly lower, as would be expected. In 2000 there were fewer recaptures again.

Walleye averaged between zero and 1.5 km per day between release and recapture, although one reportedly moved 3.0 km per day from Coteau Bay to Qu'Appelle Arm. Three walleye moved 1.5 km per day over periods of 29, 29, and 79 days, which is less than their swimming speed but may be close to their maximum net movement over one month.

If there was a mathematical fit to walleye movements, the expected number of tagged fish by location and actual recaptures by location could be used to estimate lake-wide numbers of walleye. Linear distances seemed suitable because Lake Diefenbaker is nearly one-dimensional along its axis. The observed pattern resembles random wandering of walleye, at least up to about 127 to 150 days (Figure 12). However, the available data are described about equally well by correlated directional swimming as by a "random walk."

Table 19. Distance from Coteau Bay to recapture locations, 1998 [a].

Days after tagging	1 to 30	41 to 90	91 to 130
Distance (km)	Number	Number	Number
0	119	1	0
1 ≤ 25	0	3	4
50	9	6	8
75	0	10	1
100	0	3	0
125	0	1	0
150	0	0	2
175	0	0	0
Totals	128	24	15

[a] Days refers to days after May 1 1998; Number is number of fish

Table 20. Distance from Coteau Bay to recapture locations in 1999.

Days after tagging [a]	366 to 395	401 to 430	431 to 480
(Seasonal day) [b]	(1 to 30)	(36 to 65)	(66 to 115)
Distance (km)	Number	Number	Number
0	28	4	2
1 ≤ 25	2	5	1
50	9	3	6
75	0	3	3
100	0	0	0
Totals	39	15	12

[a] Days refers to days after May 1 1998; Number is number of fish.
[b] Seasonal day in 1999 begins May 1 for comparison between years.

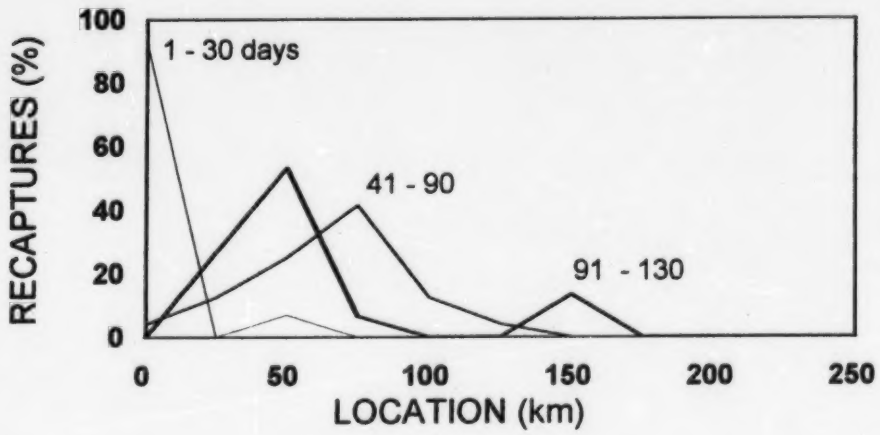

Figure 11. Walleye recaptured by location (from Coteau Bay) by anglers in 1998.

Number of days refers to time since tagging; the three periods end about one, three and four months after tagging.

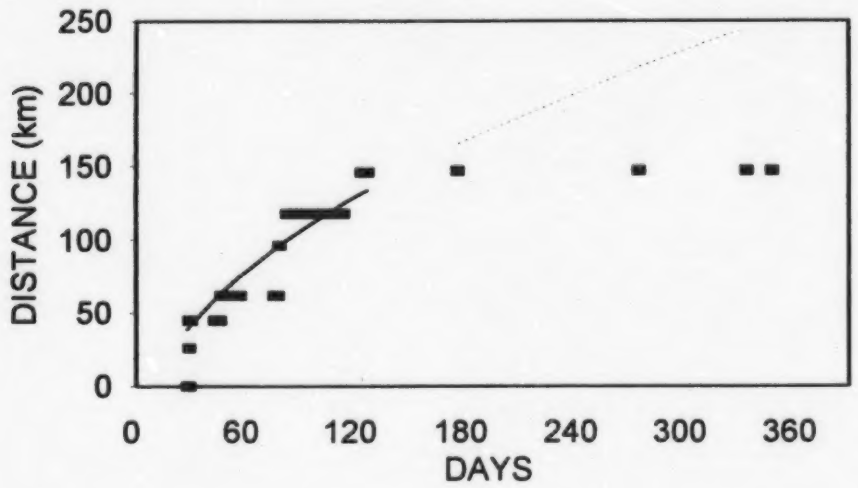

Figure 12. Furthest distance of walleye by day when recaptured by anglers in 1998.

The prediction for random wandering is shown by a solid line up to day 127 and a dotted line for later periods.

Walleye tagged at the Riverhurst tournament in June 1998 were used to test for movements from other areas into Coteau Bay the next spring. It was recognized that these walleye initially may have been spawners or residents of Riverhurst area, Coteau Bay, or elsewhere in 1998.

Preliminary thoughts suggested there was a reasonable chance of detecting some Riverhurst tags in Coteau Bay. For 274 red tags, there was a 78 % chance of catching at least one red tag, even if only 10 % of walleye at Riverhurst in June migrated into Coteau Bay the following spring — as long as 50 or more tags from both sources were caught.

In 1999, four walleye with red tags were caught in trap-nets in Coteau Bay. In 2000, two walleye were caught in Coteau Bay. Both of them were males which had also been caught in 1999. It was not possible to tell if these walleye resided year-round in Coteau Bay or returned to spawn because neither was caught outside of Coteau Bay.

3.7 REPRODUCTION

The only available long-term index of the utilization of eggs from Coteau Bay is based on the number of females caught. From 1991 to 2000, between 28 and 45 % of the eggs in captured females were collected, assuming that "spawned-out" and non-ripe females previously or eventually laid the same average number of eggs as those used. If non-ripe females were typically smaller or less fecund, the percentage might be 1/3 higher (Mathias et al. 1985). Nonetheless, this index does not consider the total number of females in this population.

A better index is the number of eggs collected versus the number in all females in Coteau Bay. The estimates of 5,800 females in 1998 and about 5,000 in 1999 indicate between 700 and 788-million eggs are typically present each year. This means between 13 and 14 % of all eggs in Coteau Bay were collected annually at spawn camp (Table 21).

The effects of this collection must be assessed against a variety of factors. Some of these are the variability of egg hatching success, year-class strengths, weather from year-to-year, the relative survivals of natural and replanted fry, and the number of females at other spawning sites. Typically, eggs, fry, and young-of-the-year walleye have low and variable survival. For moderate numbers of spawners, long time series are needed to demonstrate any relationship between spawners and progeny (Colby et al. 1979, Mathias et al. 1985).

More detailed estimates and predictions, based on size structure, were not feasible due to the lack of actual egg counts for individuals of different sizes. Maturity data were available for 127 walleye caught in summer surveys of 1995 using standard-gang gill-nets in the open lake. These comprised 23 immatures, 104 matures, and ranged from 30 to 75 cm fork-length (average 51.8 cm, standard deviation 113.83 cm) (Ron Jensen unpubl. data).

Table 21. Collection of eggs in comparison to numbers available, 1991 to 2000.

Year	Eggs collected (millions)	Number available (millions) based on females	
		Caught (%)	Population (%)
1991	60.9	184.8 (33)	...
1993	78.4	201.3 (39)	...
1994	97.7	263.1 (37)	...
1995	112.9	193.0 (59)	...
1996	93.7	155.4 (60)	...
1997	113.0	236.4 (48)	...
1998	105.0	230.7 (45)	788.8 (13)
1999	99.5	352.5 (28)	700.0 (14)
2000	96.7	176.0 (55)	...

The proportion mature (p) at each size was estimated by logistic regression, which fits a logistic curve for any fork-length (x) using the function:

$$p = \exp(y) / (1 + \exp(y)), \text{ where } y = a + b * x$$

This produced coefficients a = -10.891 and b = 0.028 for female walleye in 1995.
This predicts about 50 % of females are mature at 39 cm and 80 % at 44 cm (FISHPARM by Prager et al. 1989).

Similarly, the 1995 data were used to predict round weight from fork length:

$$\text{Log}_{10} \text{RW (kg)} = -5.586 + 3.390 * \text{Log}_{10} \text{FL (cm)},$$

where n = 126, $r^2 = 0.965$, and std dev of FL = 11.327 and RW = 1.38371.
This regression was used on individual fish to reduce the bias of under-estimating fecundity from average lengths rather than weights directly.

Sizes of individual females in 1998 and 1999 show about 10 % error if fecundity is predicted from average lengths. Females averaging 55.0 cm in 1998 would have a predicted average weight of 2.06 kg compared to actual 2.29 kg (11 % higher). Females averaged 58.9 cm in 1999, implying an average 2.59 kg compared with an actual of 2.82 kg (9 % higher).

4.0 DISCUSSION

4.1 POPULATION STATUS

Trends in several population indicators showed normal fluctuations. Only one indicator (the proportion of females) causes any concern and only for the year 2000. Careful monitoring will be required to demonstrate any changes or trends in these indicators.

Relative to other walleye spawning populations, the proportion of female spawners in Coteau Bay is quite high at 1.5 males for every female. A similar ratio was observed in Crean and Heart Lakes (Mathias et al. 1985). Nonetheless, "sex ratios" are often two or three males per female and can be eight or 10 in spawning runs (Bad Carrot Creek, Lake Lenore, Lynx River, Montreal River, and Nemeiben River in Chen et al. 1984). Very high sex ratios may indicate a natural imbalance or be seen as a symptom that populations have "declined drastically" (Colby et al. 1979). This does not apply to Lake Diefenbaker, given the male to female ratios experienced during the study.

There were few changes in sizes of walleye during the three-year survey. It is also unlikely they have declined since 1991, since recent sizes and ages in Coteau Bay approach or exceed the maximum reported in other "healthy" populations. Ages of 18 to 20 and mortality of 13 % for females are relatively good (Colby et al. 1979). Walleye in two unexploited lakes in Manitoba reach 17 and 20 years old (Home and Wapun Lakes, respectively, Mathias et al. 1985). Spawning walleye in Swan Creek, Manitoba reach 18 years and have been an egg source for a hatchery for some years (Johnston 1997). At a mortality rate of 13 %, females remain in the spawning population of Coteau Bay an average of about 7.7 years (Ricker 1975). Monitoring since 1991 should have detected serious changes in at least one cohort if they were present.

Casual observations suggest that symptoms of disease, tumours or stress are infrequent in Coteau Bay walleye. Experienced fish culture staff noted that disease rates are lower than in spawning runs previously used to collect walleye eggs for the province. One symptom noted in Lake Diefenbaker walleye was "lymphocystis," a virus that causes wart-like growths due to hyperplasia (enlarged cells) under the skin. It occurs naturally in many populations, increases during stress (spawning or handling), may be more prevalent in cooler temperatures, but is not usually fatal (Ott 1994). Occurrence was low in Coteau Bay, certainly not 10 % as seen early in the run at Crean-Heart Lakes (Mathias et al. 1985).

Other diseases probably occur in Coteau Bay. In 1998, results were obtained from necropsies of 25 female walleye selected for their old age. These showed liver tumours in 24 % of the walleye and pancreatic neoplasm in one fish or four percent (Cam Portt pers comm). These are lower incidence rates than sites in Ontario, but not negligible for a presumably uncontaminated area. Periodic visual surveys of Coteau Bay could provide a baseline. Diseases such as walleye dermal sarcoma, epidermal hyperplasia, and lymphocystis can be common. More than 15% of

walleye over 10 years old at Coteau Bay and about 35 % of all walleye in the Crean-Heart Lake spawning run showed one or more of the listed diseases (Mathias et al 1985). Some diseases would require specialized exams and specimens.

4.2 TAGGING

There is concern about stress from the extra handling, in addition to spawn-taking, required by assessment activity. This handling includes the transfer of fish into other pens, extra holding time, measuring for length, checking for previous marks (visually or by touch), and tagging or hole-punching. Some incidental damage is unavoidable but should be minimized since it will confound the issue, especially in a population with a low mortality rate.

To provide perspective, many kinds of tags show considerable losses in walleye. "Jaw tags" are metal bands attached around the maxillary bone of the jaw that have reported annual loss rates as high as 40 to 60 %. These losses are comparable to this study. Jaw tags also often have negative effects on feeding and growth rates. Further studies reported 18 % of tags were lost to angler catches and 28 % to impounding nets which snag the tags in the mesh (Newman and Hoff 1998). "Dangler" tags are typically stitched into dorsal muscles and losses range from 1 to 20 %. "Anchor" tags are plastic filaments with a T-bar or barbel end that is injected below fins, with losses of 7 to 92 % (see Newman and Hoff 1998).

The high loss rate of metal tags on Lake Diefenbaker was due to erosion of the gill cover by tag movements as a result of poor closure of the tags. These metal tags caused visible damage, especially in comparison to dorsal-punch marks, but this does not exonerate the punch marks (Ricker 1975).

There are no perfect tags because the criteria differ according to survey needs and species hardiness. Short-term studies need only a delicate attachment, while multi-year monitoring requires secure attachment and/or double-tagging to maximize retention. Other kinds of tags are available: internal tags (PIT or passive integrated transponders) can be embedded easily and then read from 10 cm with a handheld electronic reader. T-bar tags are visible, quick and suitable for angler reporting, and new fluorescent marks for injection or embedding into skin are available.

4.3 ABUNDANCE

Few reports on numbers of walleye spawning in situations like Coteau Bay are available in the literature. The maximum observed over nine years of trapping at Crean and Heart Lakes was 12,000 to 17,000 (Mathias et al. 1985). As many as 20,000 adult walleye were caught on their spawning run in the Montreal River (Lac la Ronge) in the 1940-1950's, mostly males and considerably fewer adults by 1981 (Chen et al. 1984). There were about 40,000 adults in Nipigon Bay (Lake Superior) in 1957, but this is a large bay with year-round residents and previous depletion of walleye (Ryder et al. 1968).

There are problems with assuming that Coteau Bay walleye are either a "closed" population or an "open" population. The first situation provides simpler analysis at the expense of realism; the second should reflect fish behaviour better, but becomes complex.

Mark-recapture analyses do not directly provide the total number of individual fish in the migration, especially when some arrive earlier and some die or leave before others arrive (Schwarz et al. 1993). One approach to address this is to assume that fish arrive, live or die, and depart following mathematical rules. Another is to divide the total number of walleye-days by their average length-of-stay in days to estimate the number of individuals (Hilborn et al. 1999). Use of this second method was based on its practical nature, since stays by marked fish were observed. However, fish that stay longer have greater cumulative chances of being recaptured, which biases the average upwards.

The average length-of-stay of six days seems reasonable with few reported comparisons. Reports of "spawning peaks" lasting 1 to 10 days usually refer to the number of walleye present or migrating past nets, rather than residence by individuals (Colby et al. 1979). In some northern lakes, some females disperse shortly after spawning while others remain in nearby shallow bays into early summer (Bodaly 1980). In some southern rivers, spawners drift into pools and remain sedentary for two weeks (Paragamian 1989). Some walleye remain all summer in Coteau Bay according to angler recaptures, due to preferences for 23 ° C and optimal growth in 20 to 22 ° C water (Christie and Regier 1988).

Lake Diefenbaker likely has 300,000 to 900,000 adult walleye lake-wide, based on its habitat and walleye densities in other populations (Baccante and Colby 1996). About 78% of the lake, 37,300 ha, is shallower than 30 m (Royer 1972) and presumably suitable for walleye. About half of North American lakes have between 8 and 24 adult walleye per hectare.

4.4 ANGLING

Angling in Lake Diefenbaker since 1969 has increased considerably with additional changes occurring in the 1980's. Early emphasis on and success with northern pike meant they comprised 89% of observed catches (Royer 1972). By 1983-84, 70% of anglers preferred walleye and they comprised 50 to 66% of catches (Chen 1983, Merkowsky and Chen 1985). The nature of angling continued to change with the increase in catch-and-release tournaments in the late 1980's.

Today, Lake Diefenbaker is a very important recreational lake in Saskatchewan. In the last two national sport fish surveys, it has ranked as the second most popular lake in 1990 and most popular recreational lake in the province in 1995 (Joerissen and Brickley 1998)

4.5 MOVEMENTS

Walleye from Coteau Bay ranged up to about 160 km by early September in 1998. Angling and recaptures in 1999 and 2000 did not extend up reservoir recaptures. Presumably, this is the typical range for the Coteau Bay spawning population.

4.6 REPRODUCTION

After a long period of egg collections by Saskatchewan fish culture staff at the Crean and Heart Lakes, the status of spawners was assessed by a federal agency. The conclusion was that there was no noticeable effect of these collections on several indicators which included relative strengths of year-classes (Mathias et al. 1985). These collections were described as "massive spawn-taking" and averaged 54 million eggs or 39% of the total egg capacity of all females in the run.

Naturally, weak year-classes which occurred simultaneously in Crean and Heart Lakes, as well as other lakes in the area were ascribed to observed weather patterns (Mathias et al 1985). Due to consistent demands for walleye eggs, collections ranged from 18 to 68% of the egg capacity of the 1,047 to 6,484 females annually from 1967 to 1975. There was a general tendency to higher percentages in years with lower numbers of spawners which would reinforce any natural variability. This tendency, however, did not follow through to affect year-classes. There was no correlation over the range from 23 to 150 million eggs.

Studies on walleye usually suggest little correlation between numbers of females or eggs and later abundance over considerable ranges but this is not boundless (Colby and Olver 1978; PERCIS). At high abundance, factors such as cannibalism and competition among fry and young dampen very large year-classes. At low numbers of spawners, reproduction and survival of eggs and fry become more important.

One way to minimize any potential collection effects in Coteau Bay might be to restrict collections in years with low numbers of spawners. A limit on effort, such as restricting the number of trap net nights, might make it easy to avert heroic efforts in weak years. A limit based on the number of walleye caught rather than only on number of females spawned might be more cautious since changes in numbers and sex ratio would be incorporated. This would fine tune egg collections so that the stocking program is affected as much as or more than natural reproduction in years with lower reproductive capacity.

Any direct effects of egg collections since 1991, such as mortality of fish, would likely have become apparent by 2000 if effects are cumulative and multiplicative. However, the longevity of females may mask symptoms for some time. Continued monitoring with enough intensity to detect any effect in the natural variability of populations would be required.

The effect of egg collections cannot be assessed from current literature. Experience shows that finding relationships between numbers of spawners and the number of progeny that mature to replace them is difficult for most fish species. Walleye have shown no effects on year class strength when a moderate number of spawners are stripped of their eggs for stocking programs instead of contributing to natural reproduction. Recent theory suggests that walleye may produce several replacements for each spawner at low population density (Myers et al. 1999).

Indirect effects of selecting and handling spawners like reduced numbers or quality of eggs remaining to hatch naturally would be more difficult to assess. Detailed work on one walleye run in Manitoba reveals that hatching success of eggs was higher for older females. Egg weights were higher for older and larger females and fry weights were higher for heavier eggs (Johnston 1997). Since heavier fry presumably survive better in the wild, long-term effects of selective pressure on larger spawners is possible, but likely hidden in natural variability.

5.0 CONCLUSIONS

The walleye population in Coteau Bay appears to be healthy. This is based on the large sizes and oid aged fish, especially females, the relatively low mortality of both sexes and the acceptable proportion of females in 1998-2000. Monitoring during hatchery operations of numbers of females and males, average eggs per female and percentage of eggs which hatch successfully since 1991 also indicates a sustainable situation. Only one indicator (the proportion of females) was unusually low in 2000, and may be a concern if this trend continues.

Female spawners reach 20 years old and males about 15 years in Lake Diefenbaker. Both have relatively low mortality in this population. They are substantially larger than those caught by angling in 1983 and are somewhat larger than those caught and selected for weighing in 1998 by highly motivated tournament anglers.

From angler reports of recaptures, some walleye move almost halfway and 3/4 of the way up the reservoir by July and by September respectively. There is some indication that they disperse from Coteau Bay by swimming randomly while purposeful migration is possible. More precise data are needed to confirm any pattern before that can used to estimate walleye abundance throughout the lake.

Coteau Bay has about 15,000 individual spawners, based on recaptures of tagged fish one and two years after release. It is less likely that they number up to 40,000, as estimated in 1998 using daily recaptures during tagging. Both methods have advantages and disadvantages: the first must adjust for mortality and loss of tags and recruitment over two years, while the second depends on fish being tagged and then reaching trap-net sites again without delay.

Available indicators (such as number of females, sizes and ages and mortality of spawners, and "egg quality") show no obvious trends over time. There appear to be few, if any, problems associated with the hatchery collection of eggs since 1991. Several of these indicators would require longer monitoring to detect slow changes due to natural fluctuations in walleye populations.

This assessment covers only walleye which migrate into Coteau Bay to spawn. Walleye from Coteau Bay move most of the way up the lake, and some walleye found in the Riverhurst area in June move into Coteau Bay the next spring. Data gathered during this study should not be extrapolated to other spawning populations in Lake Diefenbaker.

6.0 RECOMMENDATIONS

1. There should be continued monitoring of hatchery operations in Coteau Bay. An additional area to monitor could be physiological egg quality: based on numbers of eggs, size of eggs, hatch rates, and fry sizes for representative individual females.

2. Symptoms of disease and stress in the Coteau Bay spawning population should be monitored, at least periodically. This would act as a baseline and provide comparisons to other spawning populations in Lake Diefenbaker.

3. There should be an assessment of whether the utilization of walleye in Coteau Bay is being sustained by contributions from other spawning groups. This would mask problems in Coteau Bay and lead to impacts on both hatchery operations and the lake-wide population.

4. An estimate should be developed of the number and sizes of spawning populations in Lake Diefenbaker and any inter-mixing among sites to confirm inter-dependency.

5. Future work should examine the impacts, such as mortality from handling or stress on spawning walleye, of biological assessment, hatchery operations, and catch-and-release angling.

6. Egg collection should be fine tuned according to natural abundance of eggs each year rather than management demands. If catch rates, sizes and sex ratios are good, more eggs can be taken; otherwise fewer than average could be collected and more left to sustain weaker year-classes.

7. The stability of year classes in Coteau Bay walleye should be assessed by collecting age material based on fin-rays from spawning fish which would be more reliable than from scales and non-lethal.

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APPENDICES

Appendix 1. Walleye fry and green eggs stocked in Lake Diefenbaker since 1969.

Year	Numbers	Size
1969	3 500 000	FRY
1970	2 000 000	FRY
1971	3 250 000	FRY
1975	3 000 000	FRY
1984	1 000 000	FRY
1985	250 000	FRY
1987	800 000	FRY
1988	800 000	FRY
1991	3 080 000	GREEN EGGS
1991	2 300 000	FRY
1993	2 750 000	FRY
1994	3 000 000	FRY
1995	3 450 000	FRY
1996	3 500 000	FRY
1997	3 370 000	FRY
1998	3 500 000	FRY
1999	6 000 000	FRY
2000	3 500 000	FRY
Total Fry	**45 970 000**	
Total Green eggs	**3 080 000**	

Appendix 2. Walleye tagging information poster for anglers on Lake Diefenbaker, 1998 - 2000.

Attention Anglers
Fish Tagging Project
Some Walleye in Lake Diefenbaker have been tagged for fishery management studies
Please report all tagged Walleye to the toll free 24 hour Park Watch Line.
1-800-667-1788
The following information is required
• tag color
• specific area where tagged walleye was caught and
• tag number (if obtainable)
With your co-operation, the tagging project will help determine walleye distribution, population statistics and angler use

Appendix 3. Age length keys for mature female walleye based on surveys in: 1992, 1995 and 1998.

Females AGE																				
FL(mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 Number
281 ≤ 300																				0
320			1	1																2
340			3	1																4
360				2	2															4
380				3	2	3														8
400																				0
420					3	1														4
440					2	4														6
460						4														4
480					1	7			1											9
500						4		1	5		1		1							12
520							1	2	8											11
540						2			5				1							8
560						1		1	1				1							4
580									1	1	3		1	1	1					8
600							1		2	1	1		1	1						7
620											1	2	1	2	1	1		1		9
640										1	2		1	1					2	7
660											1	1		1	1	1	1			6
680													2	4	1	1		1		9
700											1	2			3		1	1		8
720											1			1		3	1	1		1 8
740												1		2		1				4
760																1	1		1	3
780																		1		1
781≤ 800																				0
																				Total = **146**

Appendix 4. Age- length keys for male, mature and immature, walleye based on surveys in: 1992, 1995, and 1998.

Males	AGE																			
FL(mm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20 Number
81 ≤ 100																				0
120																				0
140	1																			1
160																				0
180																				0
200																				0
220		1																		1
240																				0
260		2																		2
280		1	1																	2
300			3	1																4
320			3	2																5
340			2	5	1															8
360			1		2															3
380				7																7
400				3	4	1			1											9
420					3	4														7
440					2	2		1	1				1		1					8
460									5		2									7
480									1		2									3
500										1	1	1								3
NO DATA																				....
660																				0
680															1					1
681 ≤ 700																				0
																				Total =71